AD-A058 511 O'BRIEN AND GERE ENGINEERS INC PHILADELPHIA PA JUSTIN--ETC F/G 13/2
NATIONAL DAM SAFETY PROGRAM. SILVER LAKE DAM (DE00041), MISPILL--ETC(U)
JUN 78 J J WILLIAMS DACW61-78-C-0052

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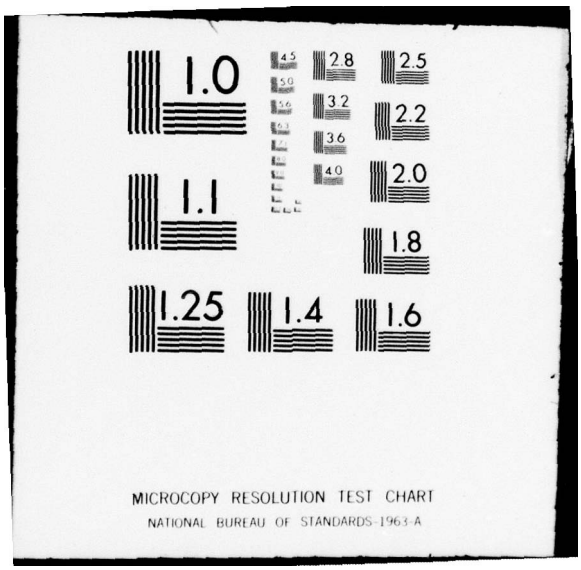
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

1

MISPILLION RIVER BASIN

MISPILLION RIVER, KENT COUNTY

DELAWARE

SILVER LAKE DAM

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

DE 00041

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE - 2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

JUNE 1978

Best copy available per Htr. on file

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DE00041	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* Phase I Inspection Report National Dam Safety Program Silver Lake Dam Kent County, Delaware		5. TYPE OF REPORT & PERIOD COVERED (9) FINAL rept. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) John J. Williams John J. [redacted]		8. CONTRACT OR GRANT NUMBER(s) (15) DACW61-78-C-0052
9. PERFORMING ORGANIZATION NAME AND ADDRESS O'Brien & Gere Engineers Inc. Justin & Courtney Div. 1617 J.F.K. Blvd. Philadelphia, Penna 19103		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 63p.
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Philadelphia Custom House, 2d & Chestnut Streets Philadelphia, Pennsylvania 19106		12. REPORT DATE (11) Jun[redacted]78 13. NUMBER OF PAGES 60
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

(6) National Dam Safety Program. Silver Lake Dam (DE00041), Mispillon River Basin, Mispillion River, Kent County, Delaware. Phase 1 Inspection Report.

17. DISTRIBUTION STATEMENT *(of the abs*

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Dams-Del
National Dam Safety Program Phase I
Silver Lake Dam,Del

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2 D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO
NAPEN-D

28 JUL 1978

Honorable Pierre S. DuPont
Governor of Delaware
Dover, Delaware 19901

Dear Governor DuPont:

Inclosed is the Phase I Inspection Report for Silver Lake Dam in Kent County, Delaware which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given on the first three pages of the report.

Based on visual inspection, available records, calculations and past operational performance, Silver Lake Dam is judged to be in fair condition. However, the spillway is considered to be seriously inadequate. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. Hydrologic and hydraulic investigations and engineering studies should be initiated within three months of the date of approval of this report to determine corrective action required to increase the capacity of the spillway to pass at least ½ PMF. Construction of an improved spillway should commence in calendar year 1979. Due to the potential for overtopping of the dam, a detailed emergency operation, drawdown and warning system should be developed by the owner within the next two months.

b. Monitoring of any changes in the structural condition of the railroad bridge abutments, which anchor the dam, should commence within three months of the date of approval of this report.

c. Within nine months of the date of approval of this report, a stability analysis of arched spillway anchorages should be performed. Any remedial measures found necessary as a result of the stability analysis study should be initiated in calendar year 1979.

d. Within one year of the date of approval of this report, trees and brush should be removed from the side slopes of the railroad embankment and a suitable controlled vegetation should be established.

A copy of the report is being furnished to Mr. Austin P. Olney, Delaware Department of Natural Resources and Environmental Control, the designated State Office contact for this Program. Within five days of the date of this letter, a copy will also be sent to Congressman Thomas B. Evans. Under the provisions of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, thirty days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia, 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely yours,

Harry V. Dutchyshyn

HARRY V. DUTCHYSHYN
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Cy Furn:
Mr. Austin P. Olney, Secretary
Department of Natural Resources and
Environmental Control

LEVEL II

1

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam: Silver Lake Dam

State Located: Delaware
County Located: Kent County
Stream: Mispillion River
Date of Inspection: May 25, 1978

ASSESSMENT OF GENERAL CONDITIONS

Silver Lake Dam consists of a steel sheet pile spillway with massive railroad bridge abutments and embankments forming the non-overflow section.

Visual inspection of the spillway steel sheet piling revealed no serious structural deficiencies. However, the structural condition of the railroad bridge is poor. A recently constructed highway bridge is located immediately downstream of the railroad bridge. This highway bridge appears to be in good condition and would act as a stabilizing factor in the event of failure of the railroad bridge. A stability analysis should consider the structures (spillway, railroad bridge and highway bridge) acting in series. This stability analysis is beyond the scope of a Phase I Report.

Hydraulics/Hydrologic analyses reveal that the embankments would be overtopped for all storms exceeding approximately fourteen (14) per cent of Probable Maximum Flood (PMF); therefore, the spillway can be considered "seriously inadequate" as cited in Engineering Technical Letter No. 1110-2, January 25, 1978. In order to satisfy criteria established by the Department of the Army, Office of the Chief of Engineers, remedial measures that should be considered include increasing the length of the spillway structure and providing an additional waterway to pass at least ½PMF without overtopping the embankments.

O'BRIEN & GERE ENGINEERS, INC.
JUSTIN & COURTNEY DIVISION

John J. Williams

John J. Williams, P.E.
Vice President

Based on visual inspection, available records, calculations and past operational performance, Silver Lake Dam is judged to be in fair condition. However, the spillway is considered to be seriously inadequate. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. Hydrologic and hydraulic investigations and engineering studies should be initiated within three months of the date of approval of this report to determine corrective action required to increase the capacity of the spillway to pass at least ½ PMF. Construction of an improved spillway should commence in calendar year 1979. Due to the potential for overtopping of the dam, a detailed emergency operation, drawdown and warning system should be developed by the owner within the next two months.

b. Monitoring of any changes in the structural condition of the railroad bridge abutments, which anchor the dam, should commence within three months of the date of approval of this report.

c. Within nine months of the date of approval of this report, a stability analysis of arched spillway anchorages should be performed. Any remedial measures found necessary as a result of the stability analysis study should be initiated in calendar year 1979.

d. Within one year of the date of approval of this report, trees and brush should be removed from the side slopes of the railroad embankment and a suitable controlled vegetation should be established.

APPROVED: Harry V Dutchyshyn

HARRY V. DUTCHYSHYN
Colonel, Corps of Engineers
District Engineer

DATE: 28 July 1978

OVERALL VIEW OF DAM

VIEW OF DAM AND RAILROAD BRIDGE

TABLE OF CONTENTS

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
NAME OF DAM SILVER LAKE DAM ID# DE 00041

SECTION I - PROJECT INFORMATION

1.1 GENERAL

a. Authority - This report is authorized by the Dam Inspection Act, Public Law 92-367, and has been prepared in accordance with contract #DACW61-78-C-0052 between O'Brien and Gere Engineers, Justin and Courtney Division, and the United States Army Corps of Engineers, Philadelphia District.

b. Purpose of Inspection - The purpose of this inspection is to evaluate the structural and hydraulic condition of Silver Lake Dam and appurtenant structures, and to determine if the dam constitutes a hazard to human life or property.

1.2 PROJECT DESCRIPTION

a. Description of Project - The spillway is a semi-circular sheet pile overflow structure approximately ninety (90) feet in length. The sheeting section is anchored at each end by massive concrete abutments of a railroad bridge which was constructed in the year 1913. Immediately downstream, the railroad bridge is adjoined by a newly constructed highway bridge.

According to a design drawing (see Figure 3) provided by the Delaware Department of Natural Resources and Environmental Control (DDNREC), Division of Soil and Water Conservation, a sloping clay blanket rests against the upstream face of the vertical sheeting.

The downstream slope of the spillway is protected with a concrete apron. The apron extends through the waterway passage of the railroad bridge and terminates upstream of the highway bridge at an area of dumped riprap.

A forty-eight inch diameter pipe is located through the sheeting on the left (looking downstream) side of the dam. The plan indicates that flow through this pipe is controlled by means of baffle boards that can be installed manually.

b. Location - Silver Lake Dam is located on the Mispillion River in Milford, Kent County, Delaware. The reservoir formed by the dam extends to the Haven Lake Dam which is located about one-half mile upstream.

c. Size Classification - According to the design drawing and data provided, the maximum height of the spillway is ten (10) feet; the reservoir storage at the spillway crest is approximately 60 acre-feet. In accordance with the Recommended Guidelines for Safety Inspection of Dams, Silver Lake Dam is in the small size category.

d. Hazard Classification - Due to urban development downstream of the dam, a significant number of human lives could be in jeopardy should the dam fail. Therefore, in accordance with the Recommended Guidelines for Safety Inspection of Dams, Silver Lake Dam is in the high hazard potential category.

e. Ownership - The dam is owned by the DDNREC and operated by the Division of Fish and Wildlife.

f. Purpose of Dam - According to DDNREC, Division of Soil and Water Convervation, the purposes of the dam are flood control, water supply and recreation.

g. Design and Construction History - The spillway was designed by the Delaware State Highway Department for the DDNREC, Division of Fish and Wildlife, and construction was completed in 1964.

h. Normal Operational Procedures - The reservoir is maintained at a fixed level. According to DDNREC, Division of Soil and Water Conservation, the 48 inch diameter discharge pipe is not being used.

1.3 PERTINENT DATA (From data furnished by DDNREC, Division of Soil and Water Conservation and the United States Army, Corps of Engineers)

a. Drainage Area - The drainage area determined from United States Geological Survey (USGS) Quadrangle Maps is about 30 square miles.

b. Discharge at Damsite - No records of maximum discharge were made available.

c. Elevation (feet above MSL)

Top of Spillway - 6.65
Streambed at Dam - 0.65
Invert of Reservoir Drain - 0.65 (48-inch diameter pipe)
Top of Railroad Embankment - 13 (estimated)

d. Reservoir Data (Water Surface Elevation at Spillway Crest)

Storage - 60 acre- feet
Area - 30 acres (from USGS Quad Sheet)

e. Spillway

Type - Steel Sheet Pile
Length - 90 feet
Structural Height - 10 feet
Slopes - Upstream 1½ Horizontal to 1 Vertical
(estimated from plans)
Slopes - Downstream - 2 Horizontal to 1 Vertical
(estimated from plans)

f. Regulating Outlet

48-inch diameter pipe, invert elevation 0.65 feet

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

A design drawing was provided by the DDNREC, Division of Soil and Water and is reproduced herein as Figure 3.

2.2 CONSTRUCTION

No construction information was made available.

2.3 OPERATION

According to the DDNREC, Division of Soil and Water, the reservoir is maintained at a fixed level. The 48-inch diameter reservoir drawdown pipe is not operated under normal conditions.

2.4 EVALUATION

Design calculations relative to the dam are unavailable.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General - The visual inspection of Silver Lake Dam was conducted on May 25, 1978. The depth of water flowing over the spillway at the time of inspection was about 0.2 feet. The weather was clear and the temperature was about sixty degrees. No underwater areas were inspected.

b. Spillway - The spillway is constructed of steel sheeting placed in a semi-circle. The sheeting is in good condition: horizontal and vertical alignment indicate no apparent movement in the structure. The concrete apron on the downstream side of the spillway appears to be free from cracks and spalls in the portions visable. However, a depression at the center of the apron was noted during the inspection. This depression is not indicated on the design plan. The plan, however, does indicate a notch in the sheeting which was not observed during the inspection.

The 48-inch diameter pipe located on the left side of the spillway was not discharging at the time of inspection. The baffle boards which control flow through this pipe could not be observed due to the water level.

c. Non-Overflow Section - The spillway is anchored by the concrete wing walls of a railroad bridge; the interconnection between the sheet piling and the wing wall is made by placement of a concrete plug at both ends of the spillway. The concrete plugs appear to be in good condition; no seepage was observed at the joints.

The wing walls of the railroad bridge show significant deterioration and structural stress. Concrete aggregate is exposed on the top surface of the wing walls and major horizontal and vertical cracks extend throughout the wing walls and endwalls of the concrete abutments. Aggregate is exposed in the walls in the lower half of the vertical height.

A new concrete highway bridge, which appears to be in excellent condition, is located immediately downstream of the railroad bridge. Three corrugated metal pipe arches, each with a span of about fifteen feet, form the waterway under this bridge.

The earth embankment portions of both bridges appear to be in good condition. Although the slopes are unprotected, no indication of seepage, erosion or instability were noted.

d. Reservoir Area - The reservoir perimeter is sparsely developed and supports a dense growth of brush and trees. No indication of slope instability was noted during the inspection.

e. Downstream Channel - The left bank of the outlet channel downstream of the highway bridge is lined with steel sheet piling for a distance of about three hundred feet. The right bank in the same area is protected with broken concrete slabs which serve as riprap slope protection. Commercial establishments are located on the property adjacent to both banks. Further downstream, the channel continues through the community of Milford.

The Mispillion River downstream of the dam is subject to the tidal influence of the Delaware River.

3.2 EVALUATION

No significant deficiencies relative to the spillway were noted during the Phase I Visual Inspection.

The concrete wing walls supporting the railroad bridge abutments show indications of structural stress. However, the recently constructed highway bridge located immediately downstream of the railroad bridge appears to be in good condition and may act as a second dam in the event of failure of the railroad bridge.

SECTION 4 - OPERATIONAL PROCEDURES

According to the DDNREC, Division of Soil and Water, the reservoir is maintained at a fixed level. The 48-inch diameter low level discharge is closed and is currently not in use. A review of the design plan indicates that handles are provided on the baffle boards to allow for manual removal. No flood warning system is in existence.

SECTION 5 - HYDRAULIC/HYDROLOGIC

In accordance with the Recommended Guidelines for Safety Inspection of Dams, the Spillway Design Flood used to evaluate the hydraulic capabilities of Silver Lake Dam is the Probable Maximum Flood (PMF). The PMF was estimated from probable maximum precipitation data published in Hydrometeorological Report No. 33.

Rainfall data was modified to reflect storm pattern and basin size by using standard factors. Snyder coefficients were provided by the Department of the Army, Philadelphia District, Corps of Engineers. This data was developed and entered into the HEC-I computer program.

Due to the relationship between Haven Lake Dam (DE 00042) and Silver Lake Dam, the reservoirs were routed in series: the discharge hydrograph for Haven Lake Dam being used as the inflow hydrograph to Silver Lake Dam. The additional drainage area contributing to Silver Lake is about 0.6 square miles. It is not considered significant to the analysis.

The flood routing performed indicated that the maximum discharge is about 44,700 cfs and that the railroad embankment would be overtopped by a maximum depth of about 10 feet. The duration of overtopping is about fourteen (14) hours. This is based on the assumption that no other overflow areas exist along the shoreline. Further analysis reveals that the embankments would be overtopped for all storms exceeding approximately fourteen (14) per cent of PMF.

A drawdown analysis was performed to determine the time required to drain the reservoir. The 48-inch diameter pipe was used as the discharge structure for this analysis. The crest elevation was assumed as the starting water elevation and inflow was considered to be negligible. Under these conditions, the estimated time to drain the reservoir is thirteen (13) hours. This represents a minimum time with no consideration given to downstream constraints such as safe discharge velocities or flows.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observation - No indications of structural stress were evident during the inspection of the sheet piling spillway. A depression in the apron downstream of the center of the sheeting was noted, but it could not be determined whether this was by design or due to foundation settlement.

The concrete walls of the railroad bridge abutments which anchor the spillway sheet piling appear to be in poor structural condition.

b. Design and Construction Data- A design drawing was provided by the DDNREC, Division of Soil and Water Conservation. Design data and information relative to the hydrologic and hydraulic computations are not available.

c. Operating Records - Operating records were not made available.

d. Post Construction Changes - No post construction changes have been reported.

e. Seismic Stability - Silver Lake Dam is located on the Mispillion River in the Atlantic Coastal Plain physiographic province. The topography reveals a gently, rolling land surface with elevations ranging from sea level to about sixty feet (MSL). Foundation materials consist of recent alluvium deposits and silty to clayey sands and granular unconsolidated sediments of the Pleistocene Columbia formation. Bedrock is not a consideration for foundation conditions at this location.

The site is located within zone one as shown on the Seismic Zone Map of Contiguous States. Projects located in this zone require no earthquake analysis provided they are not within the influence area of an active fault.

f. Evaluation - The stability of the dam is dependent in part upon the ability of the massive railroad bridge abutments to support the steel sheeting. The structural condition of the concrete walls of the railroad bridge is poor. Additional stability analysis should consider the three structures (spillway, railroad bridge and highway bridge) acting in series.

Hydrological and hydraulic studies indicate that the PMF would overtop the embankment for a considerable period of time. It is reasonable to assume that the embankments were not designed to withstand an overtopping condition. The possibility of embankment failure under this circumstance is significantly increased by the period of time that the embankment is exposed to overtopping. A stability analysis of the railroad bridge structure and evaluation of embankments under these conditions is beyond the scope of a Phase I Report.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety - The spillway is hydraulically inadequate to pass the PMF without overtopping the railroad bridge embankments; the estimated capacity of the spillway is about fourteen (14) per cent of the PMF. During the period of overtopping, failure of the railroad embankment is a possibility.

b. Adequacy of Information - Information relative to the structural design of the spillway and railroad is unavailable.

c. Urgency - Further Hydrological/Hydraulic evaluation of the dam is recommended within a reasonable period of time.

d. Additional Investigations - Hydrological/Hydraulic studies should be made to determine the additional discharge capacity necessary to pass at least the ½PMF without damaging the railroad embankments.

7.2 REMEDIAL MEASURES

a. Remedial measures that should be considered include increasing the length of the spillway structure and providing an additional waterway passage to pass at least ½PMF without overtopping of the embankments.

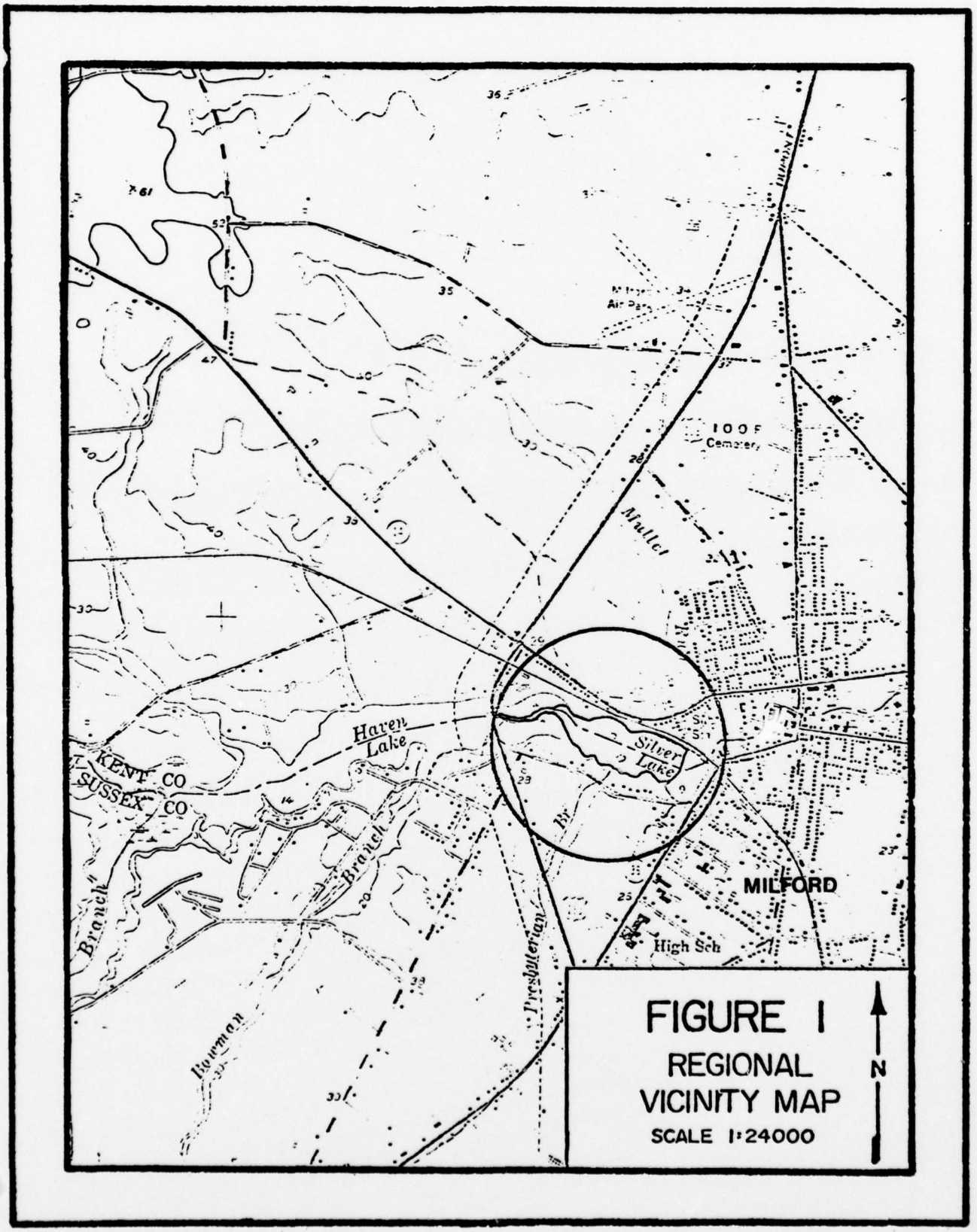
b. O&M Maintenance and Procedures - A regular maintenance program should be established to:

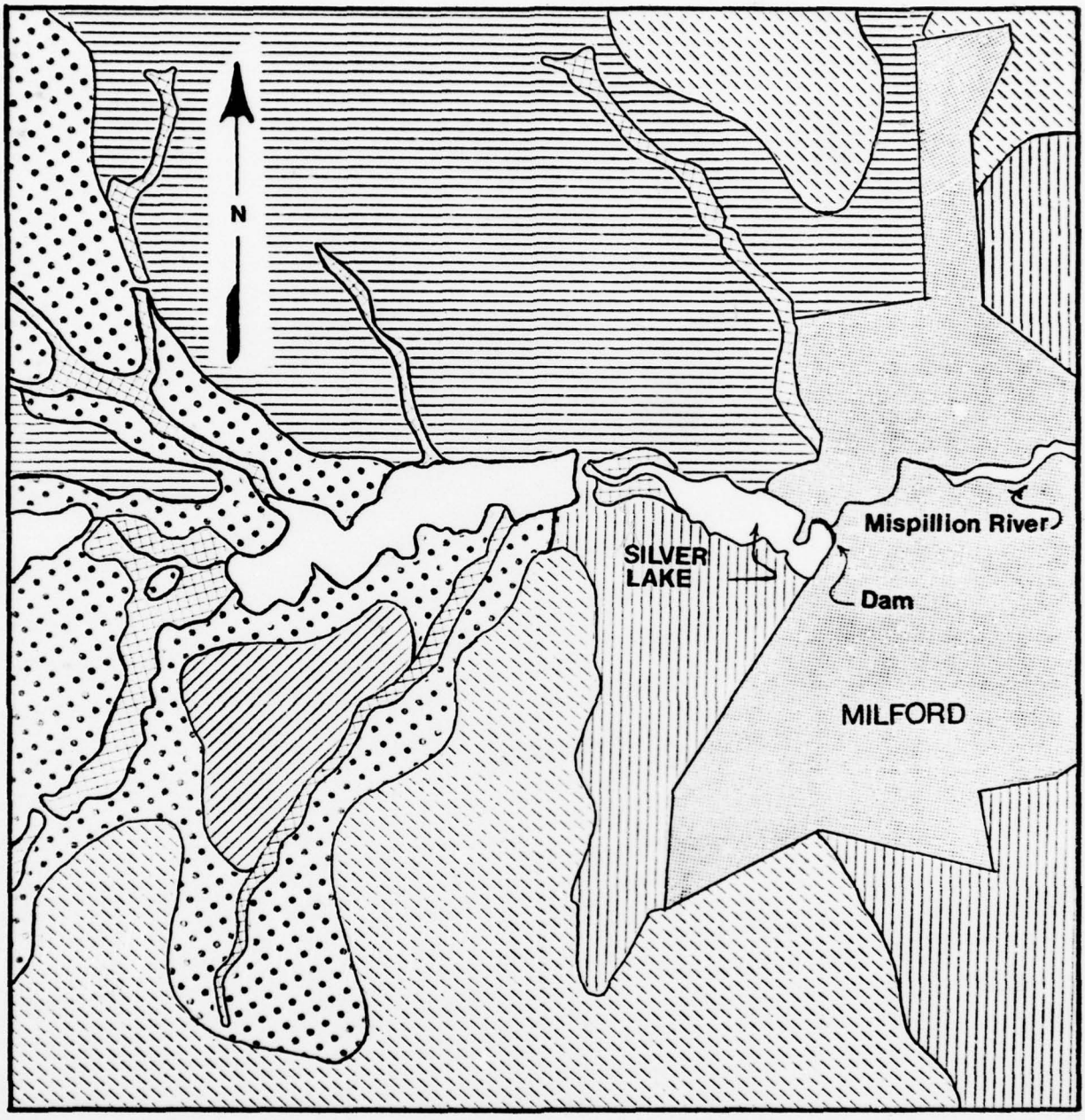
Monitor any changes in the structural condition of the railroad bridge

Regularly operate the regulating mechanism on the discharge pipe

Maintain a controlled vegetation cover on the sideslopes of the railroad embankment.

FIGURES


I O O F
Cemetery
Mullet
Haven
Lake
Silver
Lake
KENT CO
SUSSEX CO
Branch
Branch
Bowman
Presbyterian
MILFORD
High Sch
FIGURE 1
REGIONAL
VICINITY MAP
SCALE 1:24000
N



LEGEND

AM24 - Sandy and silty soil

AM2 - Sandy soil

AM2/24 - Sandy soil with some silt

AM23 - Sandy soil, poorly graded

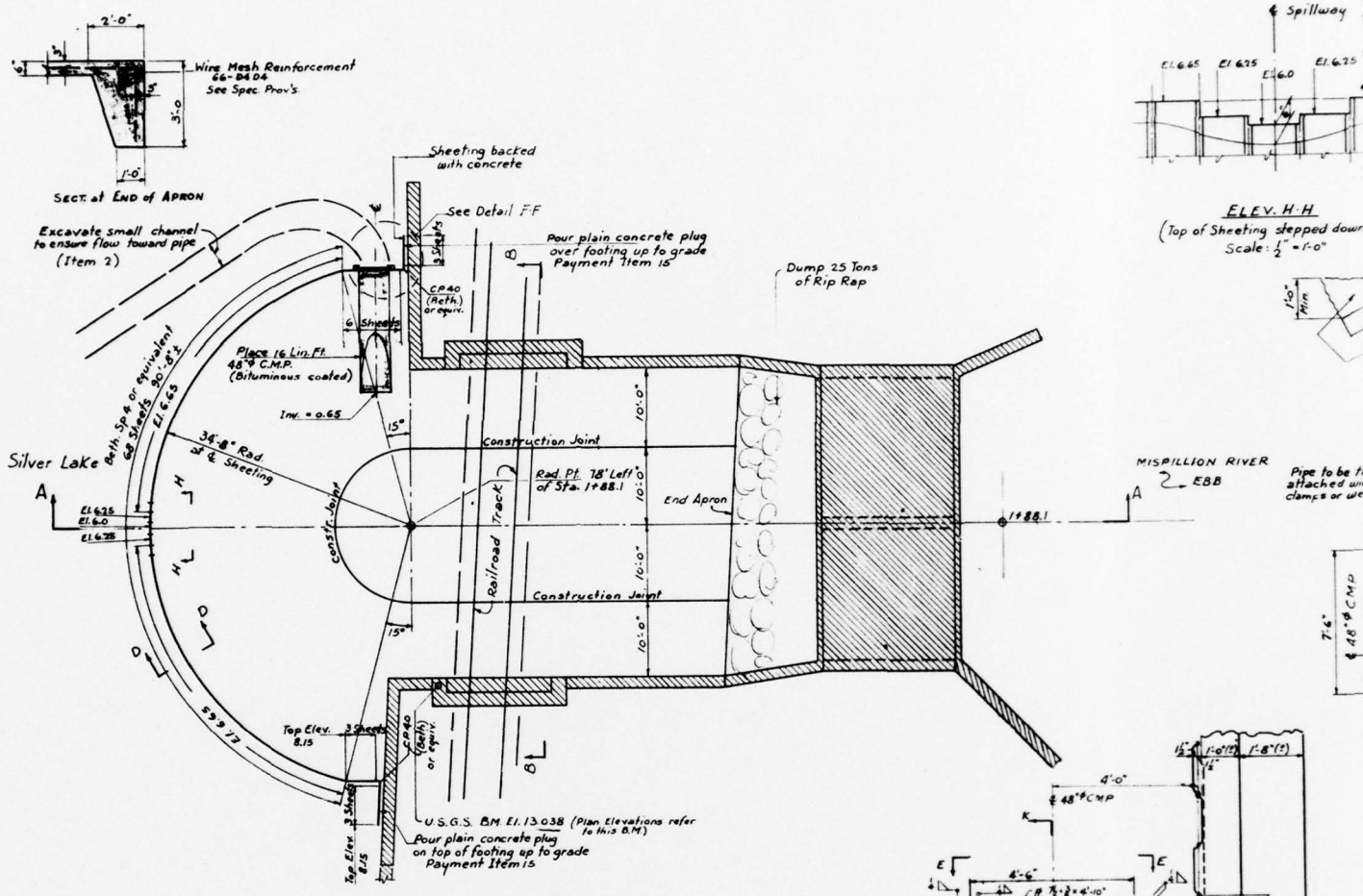
AR-Z - Alluvial gravel, sand, silt and clay; rich in organic material

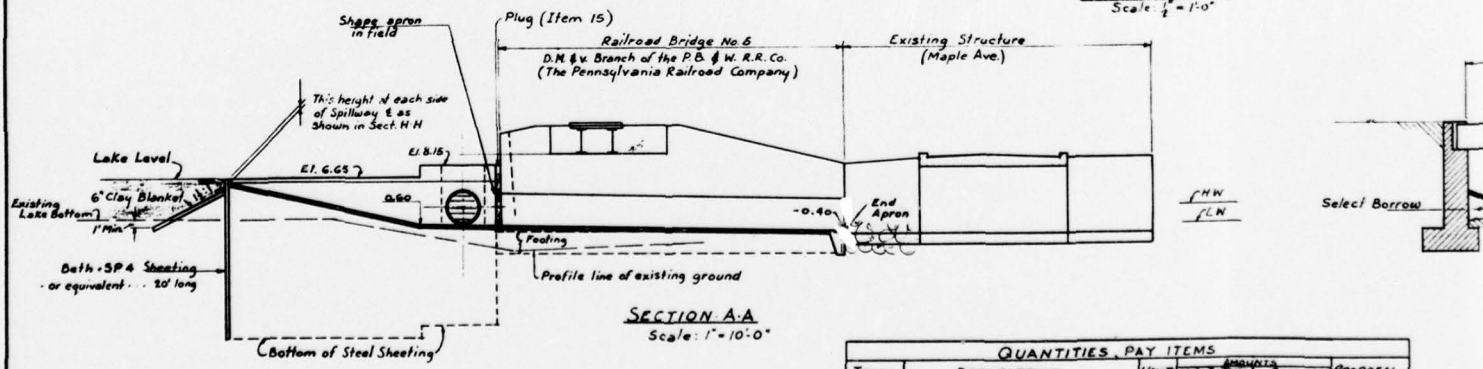
AM12/23 - Gravelly, sandy soil; poorly graded

Milford, DE

FIGURE 2

GEOLOGIC MAP





Quantities, Pay Items

Item	Description	Un. T	Amounts Main Structure	Amounts Race	Proposal
2	Excavation	C.Y.	30	5	80
7	Select Borrow	C.Y.	308	—	350
15	Portland Cement Concrete Pavem't.	C.Y.	79	3	85
21	Wire Mesh Reinforcement	S.F.	4200	—	4200
29	48"ø Corrugated Metal Pipe (Bit. Coat)	L.F.	16	—	16
—	Steel Sheet Piles	L.F.	1660	255	1915
—	Control Gate and Assembly	—	LS	—	LS
—	Clay Blanket (6")	S.Y.	133	—	150
64	Dumped Rip Rap	Ton	25	10 Tons	35

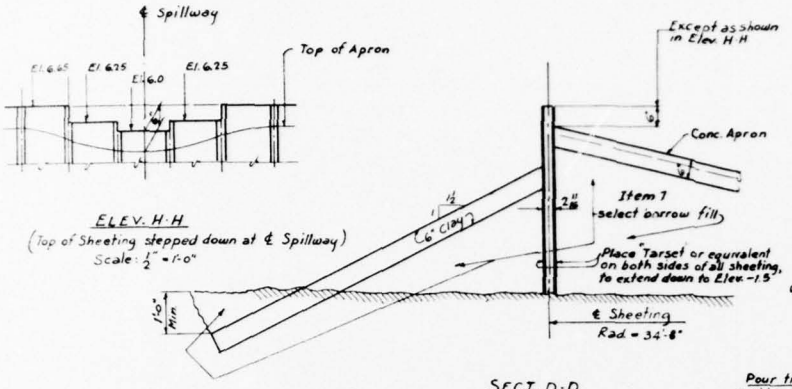
REVISIONS

COUNTY	CONTRACT	F.A.P. OR S.R. NO.	STATE	FED. AID PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
KENT & SUSSEX	64-02-001	2	DEL.		1964	1	1

SILVER LAKE SPILLWAY, MILFORD, DEL.

NOTES

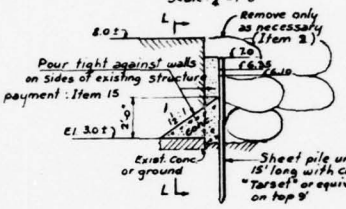
Location: In the City of Milford on Maple Ave.
Specifications: Standard Specifications of DSHD
Special Provisions of this contract.



ELEV. H-H
(Top of Sheeting stepped down at ℄ Spillway)
Scale: 1/2" = 1'-0"

SECT. D-D
Scale: 1/2" = 1'-0"

ELEV. L-L
Scale: 1/4" = 1'-0"



SECT. M-M
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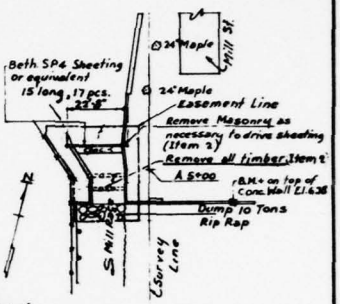
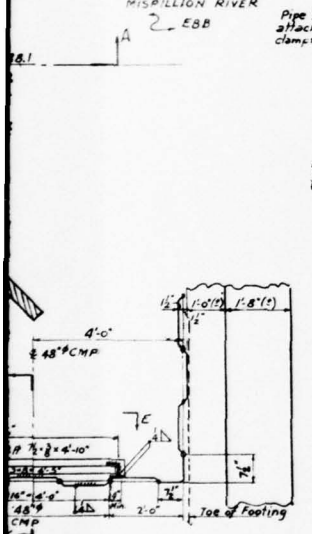
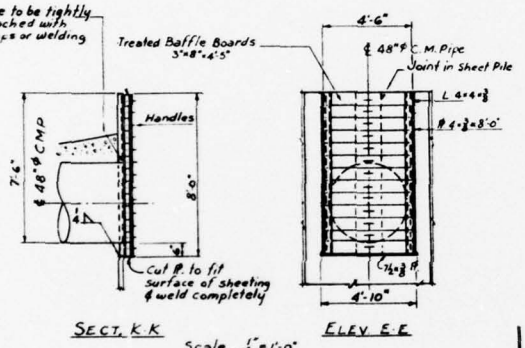


PLAN AT MILL RACE (on Mill St.)
Scale: 1" = 30'

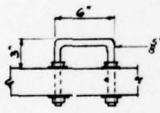


DETAIL F-F
Scale: 1/2" = 1'-0"

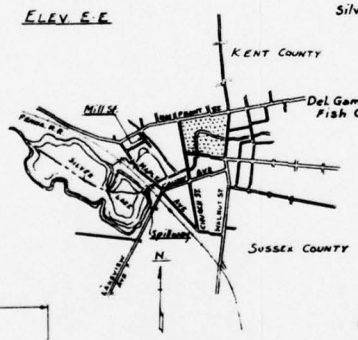


SECT. K-K
Scale: 1/4" = 1'-0"

ELEV. E-E



HANDLE DETAIL
(put one on each board)



LOCATION PLAN
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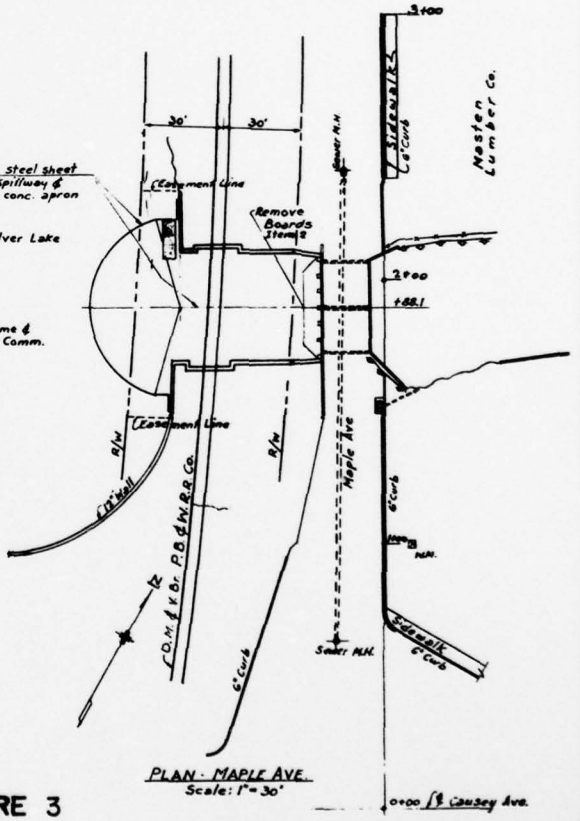
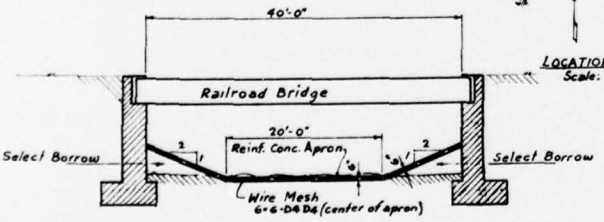


PLAN - MAPLE AVE.
Scale: 1" = 30'



SECTION B-B
Scale: 1" = 10'-0"

Y ITEMS			
UNIT	Main Structure	Race	PROPOSAL
C.Y.	30	5	40
C.Y.	308	—	350
C.Y.	79	3	85
S.F.	4200	—	4200
L.F.	16	—	16
L.F.	1660	255	1915
—	LS	—	LS
S.Y.	135	—	150
Ton	25	10 Tons	35

FIGURE 3

RECOMMENDED January 24, 1964
C. Powell Smith
CHIEF PLANNING & DESIGN DIV.

RECOMMENDED 196
ASSISTANT CHIEF ENGINEER

APPROVED 1/24 1964
Jas. S. Robinson
Asst. CHIEF ENGINEER

APPROVED 1-24 1964
DIRECTOR OF OPERATIONS

DELAWARE STATE HIGHWAY DEPARTMENT

SILVER LAKE SPILLWAY
MILFORD, DEL.

D. RBS	SCALE	APPROVED BY:
T. A.W.R.	As Noted	
C.J.B. 12/16/64		BRIDGE ENGINEER

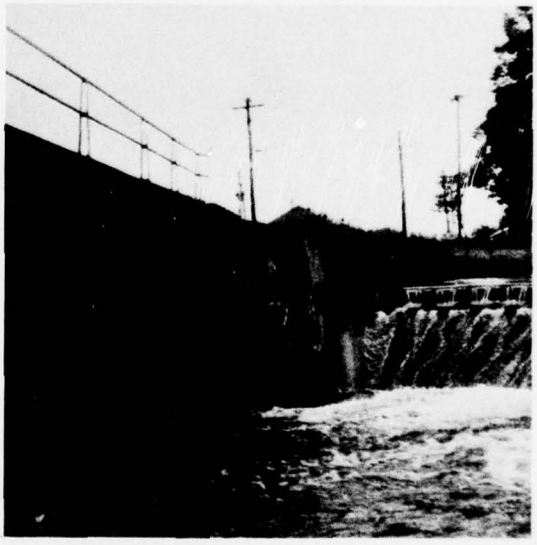
APPENDIX

PHOTOGRAPHS

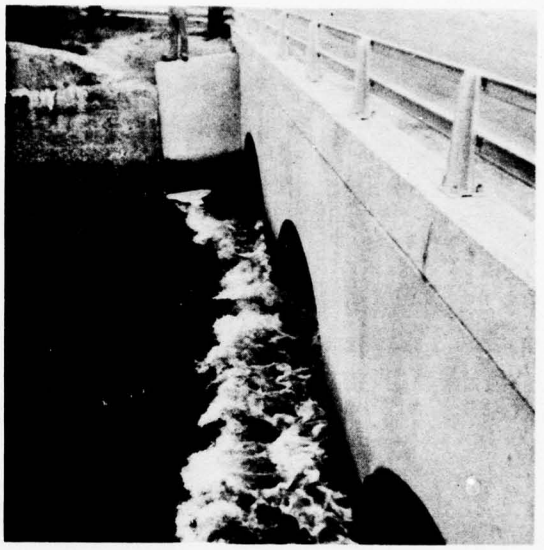
DEPRESSION AT CENTER OF DAM

DISCHARGE PIPE AT LEFT ABUTMENT OF DAM

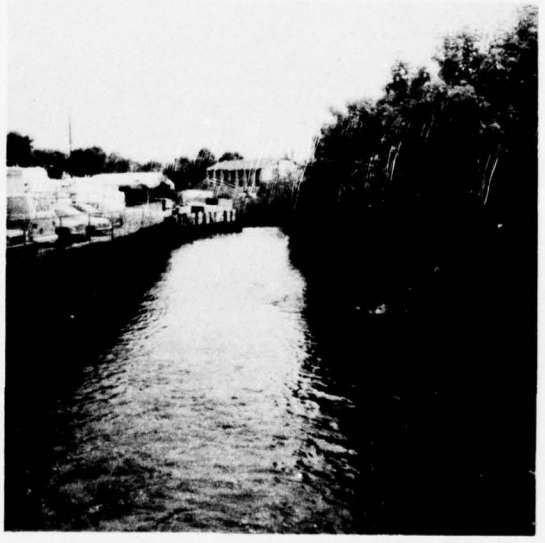
CRACK IN RAILROAD BRIDGE WINGWALL (LEFT ABUTMENT)



VIEW OF CRACK AND EXPOSED AGGREGATE IN RAILROAD BRIDGE ENDWALL (RIGHT ABUTMENT)



FLOW AT DOWNSTREAM HIGHWAY BRIDGE



VIEW OF DOWNSTREAM CHANNEL

FIELD INSPECTION REPORT

Check List
Visual Inspection
Phase 1

Name Dam Silver Lake Dam County Kent State Delaware Coordinators Mr. Krishna Patel Division Engineer

Date(s) Inspection May 25, 1978 Weather Sunny Temperature 65°

Pool Elevation at Time of Inspection 6.25± M.S.L. Tailwater at Time of Inspection N/A M.S.L.

Inspection Personnel:

Mr. George C. Elias

Mr. Frank E. Falcone

Mr. Richard E. Horvath

Mr. Richard E. Horvath Recorder

Accompanied by:

Mr. Krishna G. Patel, Division Engineer, Delaware Department of Natural Resources and Environmental Control, Division of Soil and Water Conservation.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEE PAGE ON LEAKAGE		
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	No seepage or erosion was evident at the structure/embankment junction. The spaces between the sheeting and concrete bridge abutment walls appear to be effectively closed by concrete plugs.	
DRAINS	None noted.	
WATER PASSAGES	No indication of erosion or cracks were observed in the concrete apron of the spillway.	A depression in the concrete apron was observed. No depression was shown on the plans.
FOUNDATION	Not observed.	

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	No cracking was noted in the concrete portion of the spillway. However, significant cracking and spalling were noted in the wingwalls and endwalls of the supporting railroad bridge abutment.	
STRUCTURAL CRACKING	Significant structural cracking was noted in the concrete wingwalls and endwalls of the supporting railroad bridge abutment.	
VERTICAL AND HORIZONTAL ALIGNMENT	Vertical and horizontal alignment of the steel sheeting appeared to be good.	
MONOLITH JOINTS	N/A	
CONSTRUCTION JOINTS	Concrete plugs were apparently cast directly against the existing concrete wingwalls of the railrod bridge. No joint material was observed in the joints. No movement was evident along the joints.	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None Noted.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None Noted.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	None Noted.	
VERTICAL AND HORIZONTAL ALINEMENT OF THE CREST	The alignment of the railroad embankment showed no indication of settlement and appeared to be in line horizontally.	
RIPRAP FAILURES	N/A	

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	No cracking or spalling was observed in the portions of the concrete apron visible.	
INTAKE STRUCTURE	Not observed.	
OUTLET STRUCTURE	N/A.	
OUTLET CHANNEL	The slopes of the outlet channel are protected for about 400 feet downstream; steel sheeting on the left bank, broken concrete slabs on the right bank.	
EMERGENCY GATE	N/A	

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SHEETPILE WEIR	The steel sheeting which forms the crest shows only minor signs of corrosion.	
APPROACH CHANNEL	N/A	
DISCHARGE CHANNEL	N/A	
BRIDGE AND PIERS	N/A	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	The reservoir slopes are well covered with vegetation and no erosion or slope failure was noted.	
SEDIMENTATION	The degree of sedimentation could not be determined.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	The channel immediately downstream of the spillway is constricted by the crossing of two bridges.	
SLOPES	The channel slopes are protected by steel sheeting and broken concrete slabs for a distance of about 400 feet downstream.	
APPROXIMATE NO. OF HOMES AND POPULATION	The downstream channel flows through the community of Milford, Delaware. The population of Milford is about 5,700.	

HYDROLOGIC AND HYDRAULIC CALCULATIONS

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	1	R.E.H	5/29/79	1800 001

PMF Comps

Drainage Area = 30 sq miles — From USGS Quad Sheet 7½ MIN series

PMP - 6 hr duration, 10 sq miles, Zone 6
= 28"

- Isohyetal "fit" reduction factor = 175 %
- Depth - Area - Duration adjustment = 91 %

adjusted PMP ⇒ [28" - .175(28")] .91 = 21"

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	2	RE H	5/29/78	1800 001.19

TIME (Hrs)	% 6 hr PMP	Σ 6 Hr PMP	Incr PMP	
.5	.30	6.3	6.3	①
1.0	.50	10.5	4.2	②
1.5	.58	12.2	1.7	③
2.0	.65	13.7	1.5	④
2.5	.70	14.7	1.0	⑦
3.0	.75	15.8	1.1	⑤
3.5	.80	16.8	1.0	⑧
4.0	.85	17.9	1.1	⑥
4.5	.88	18.5	.6	⑫
5.0	.93	19.5	1.0	⑨
5.5	.96	20.2	.7	⑪
6.0	1.00	21.0	.8	⑩

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	3	REH	5/29/78	1800001 199

	RAINFALL		RUNOFF		LOSSES	
	Σ	INC	Σ	INC	Σ	INC
5	.6	.6	0	0	.6	.6
10	1.3	.7	0	0	1.3	.7
15	2.1	.8	.3	.3	1.8	.5
20	3.2	1.1	.8	.5	2.4	.6
25	4.3	1.1	1.5	.7	2.9	.4
30	5.8	1.5	2.6	1.1	3.2	.4
35	10.0	4.2	6.2	3.6	3.8	.6
40	16.3	6.3	12.1	5.9	4.2	.4
45	18.0	1.7	13.7	1.6	4.3	.1
50	19.0	1.0	14.7	.9*	—	.1*
55	20.0	1.0	15.6	.9	—	.1
60	21.0	1.0	16.6	.9*	—	.1*

* Assume runoff loss rate = .2"/hr

CN = 70

SNYDER'S PARAMETERS

$C_t = .9$ and $C_p = .310$ - Provided by the Dept of the Army, Phil Dist., Corps of Engrs

$L = 8.7$ miles $L_{CA} = 4.35$ miles

$T_p = C_t(L L_{CA})^{.3} = 2.68$

$C_p = .48$

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	4	REA	5/29/78	1800.001.3

STAGE - STORAGE

From USGS Quadrangle Sheet, 7½ min. series

Area @ El. 9 = 30.3 Ac – Assume spillway crest

Area @ El. 10 = 45.9 Ac $\Delta \text{Area}/\text{Ft} = 15.6 \text{ Ac/Ft}$

Assume Area varies linearly with stage

$$A = (45.9 - 30.3)d + 30.3$$

$$= 15.6\,d + 30.3$$

$$S = \int A$$

$$\therefore \text{Storage} = 7.8\,d^2 + 30.3\,d$$

STAGE	d (Ft)	STORAGE (Ac Ft)
6.65	0	0
8.65	2	91.8
10.65	4	246.0
12.65	6	462.6
14.65	8	741.6
16.65	10	1083.0
17.0	10.35	1149.2
19.0	12.35	1563.9
21.0	14.35	2041.0
24.0	17.35	2874.0

JUSTIN & COURTNEY, INC.
Division of O'Brien & Gere Engineers, Inc.
PHILADELPHIA, PA

SHEET NO. 5 OF _____

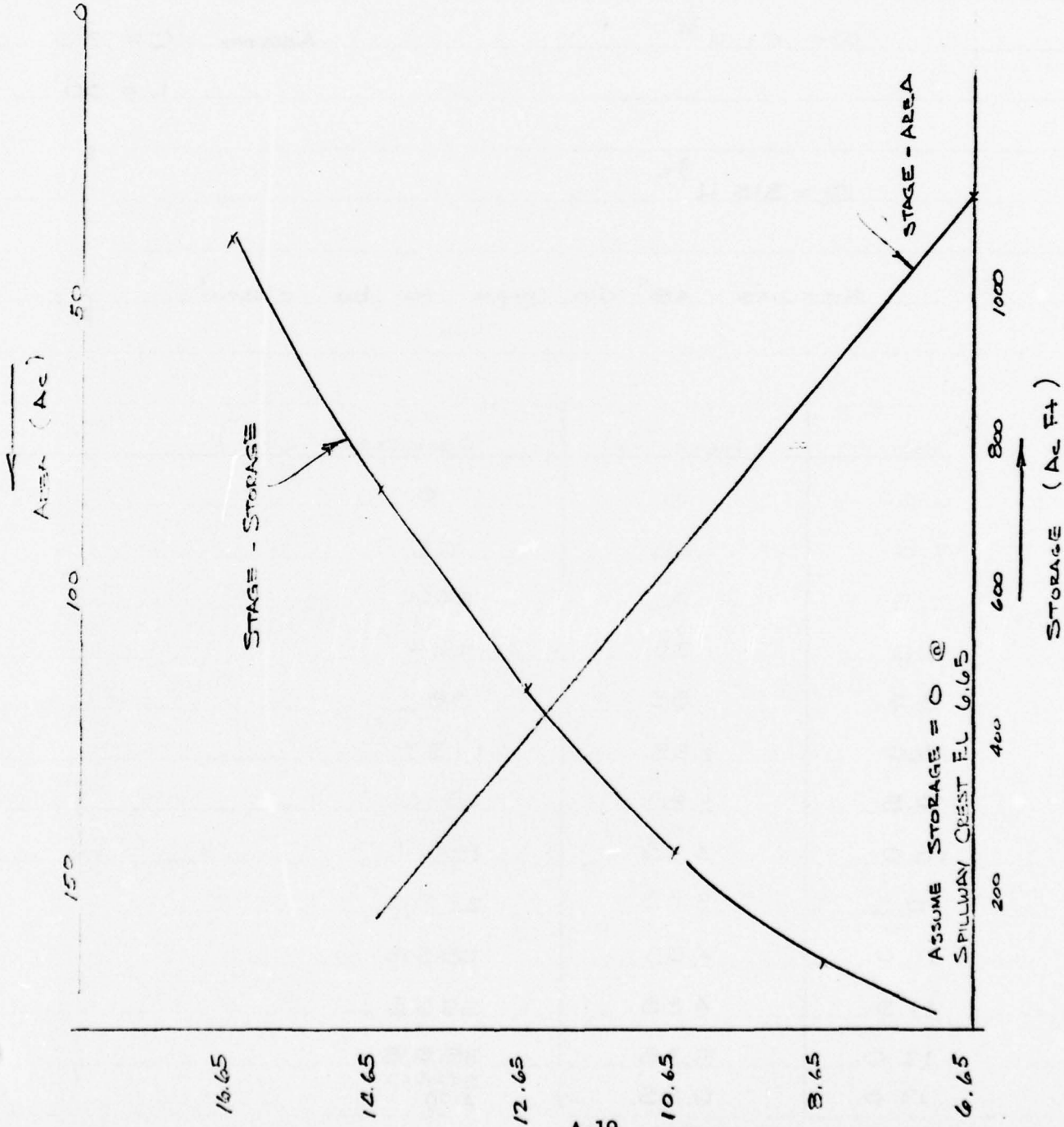
DATE 5/30/78

NAME OF CLIENT Corps of Engrs

COMP. BY REH

PROJECT Silver Lake Dam

CHECKED BY _____



O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	6	REN	5/29/78	1800.001 -1

STAGE - DISCHARGE RELATIONSHIP - Dam Spillway

$Q = C L H^{3/2}$

ASSUME $C = 3.5$

$L = 90'$

$Q = 315\ H^{3/2}$

ASSUME 48" dia pipe to be closed

Elev	Head (ft)	Discharge (cfs)
6.65	0	0
7.0	.35	65
7.5	.85	246
8.0	1.35	494
8.5	1.85	793
9.0	2.35	1135
9.5	2.85	1516
10.0	3.35	1931
10.5	3.85	2380
11.0	4.35	2858
11.5	4.85	3365
12.0	5.35	3898
13.0	6.35	5040

O'BRIEN&GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	6A	REH	6/14/78	18100 001-199

STAGE - DISCHARGE RELATIONSHIP - RAILROAD BRIDGE

El 13 Top of Embankment
El 9.5 Low Chord
El 0.65 Invert

Elevations are estimated from plan drawing

$$H = \left(1 + Ke + \frac{29 n^2 L}{r^{1.33}}\right) \frac{V^2}{2g}$$

$$V = \sqrt{42.4\, H}$$

Flow Area = $40 \times 9 = 360$ ft²

Wp = 98'

r = 3.67 $r^{1.33}$ = 5.64'

L = 20'

n = .015

Ke = .5

Assum. TW = 6.5'

Elev	H	V	Q (cfs)	
13	3.5	12.2	4392	control
12	2.5	10.3	3708	
11	1.5	8.0	2880	
10	.5	4.6	1656	

For simplification, the spillway has been assumed to control up to elev 11.0 (no tailwater is considered). Above elev 11.0, pressure and weir flow (relative to the railroad bridge) are assumed to control (a tailwater elev. equal to 9.5 was used).

$$Q_{weir} = C L H^{3/2} = 3(400) H^{3/2} = 1200 H^{3/2}$$ estimated

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	6B	REH	6/14/78	1800.001

Pressure Flow				Weir Flow		
Elev	HP	V-1 (fps)	Ds (cfs)	Hw	Ds (cfs)	Ds (total)
14	4.5	13.8	4968	1	1200	6168
15	5.5	15.3	5508	2	3394	8902
16	6.5	16.6	5976	3	6235	12211
17	7.5	17.8	6408	4	9600	16008
18	8.5	19.0	6840	5	13416	20256
19	9.5	20.1	7236	6	17636	24871
20	10.5	21.1	7596	7	22224	29820
21	11.5	22.1	7956	8	27153	35109
22	12.5	23.0	8280	9	32100	40680
23	13.5	23.9	8604	10	37947	46551
24	14.5	24.8	8928	11	43779	52707

COMPUTER INPUT

STAGE	6.5	7	9	11	13	15	17	19	21	24	FT
STORAGE	0	12	114	279	507	780	1149	1564	2041	2874	A.FT
DISCHARGE	0	65	1135	2858	4392	8902	16008	24872	35109	52707	CFS

JUSTIN & COURTNEY, INC.
Division of O'Brien & Gere Engineers, Inc.
PHILADELPHIA, PA

SHEET NO. 6C OF _____

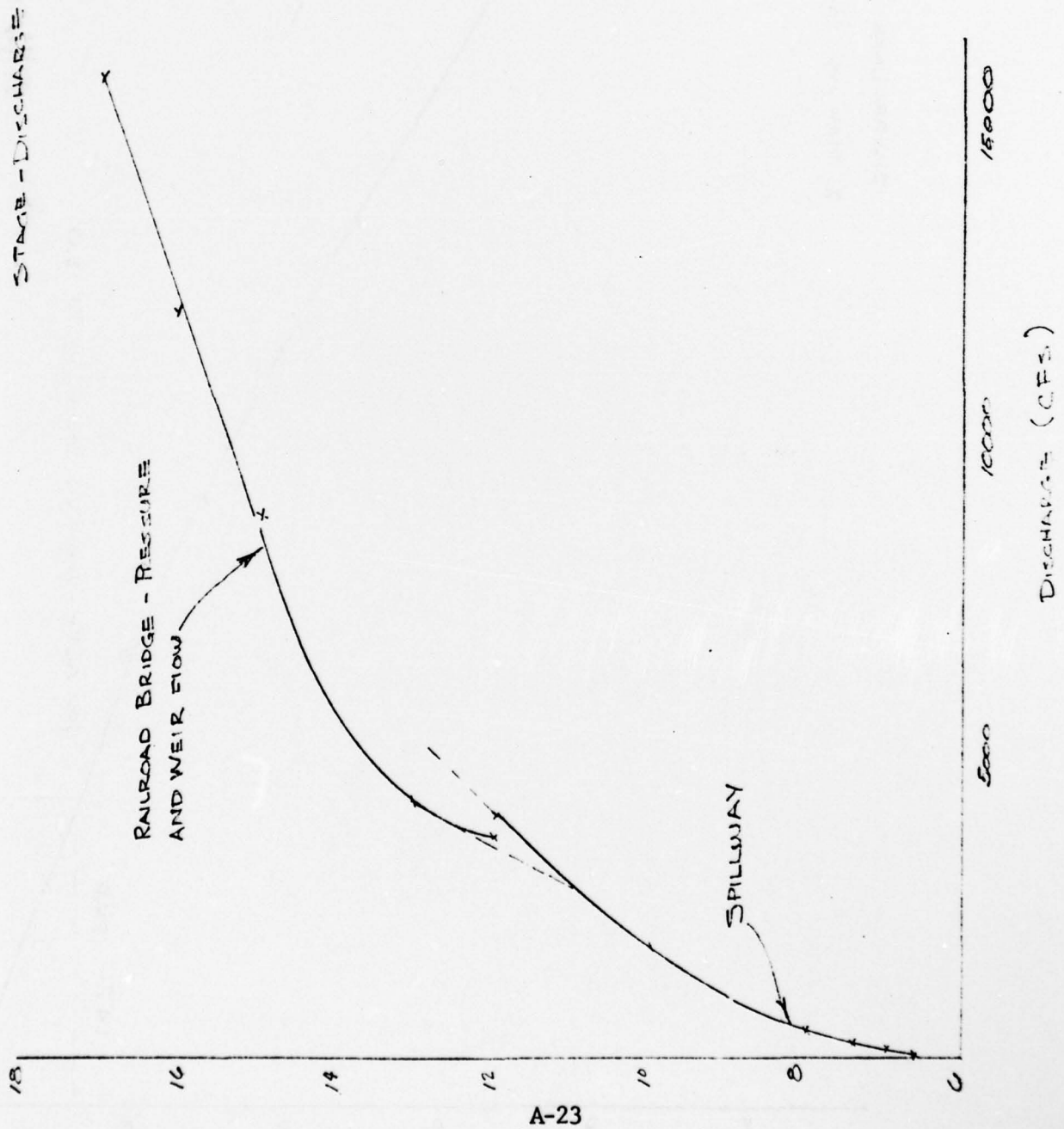
DATE 6/19/78

NAME OF CLIENT Corps of Engrs

COMP. BY JEL

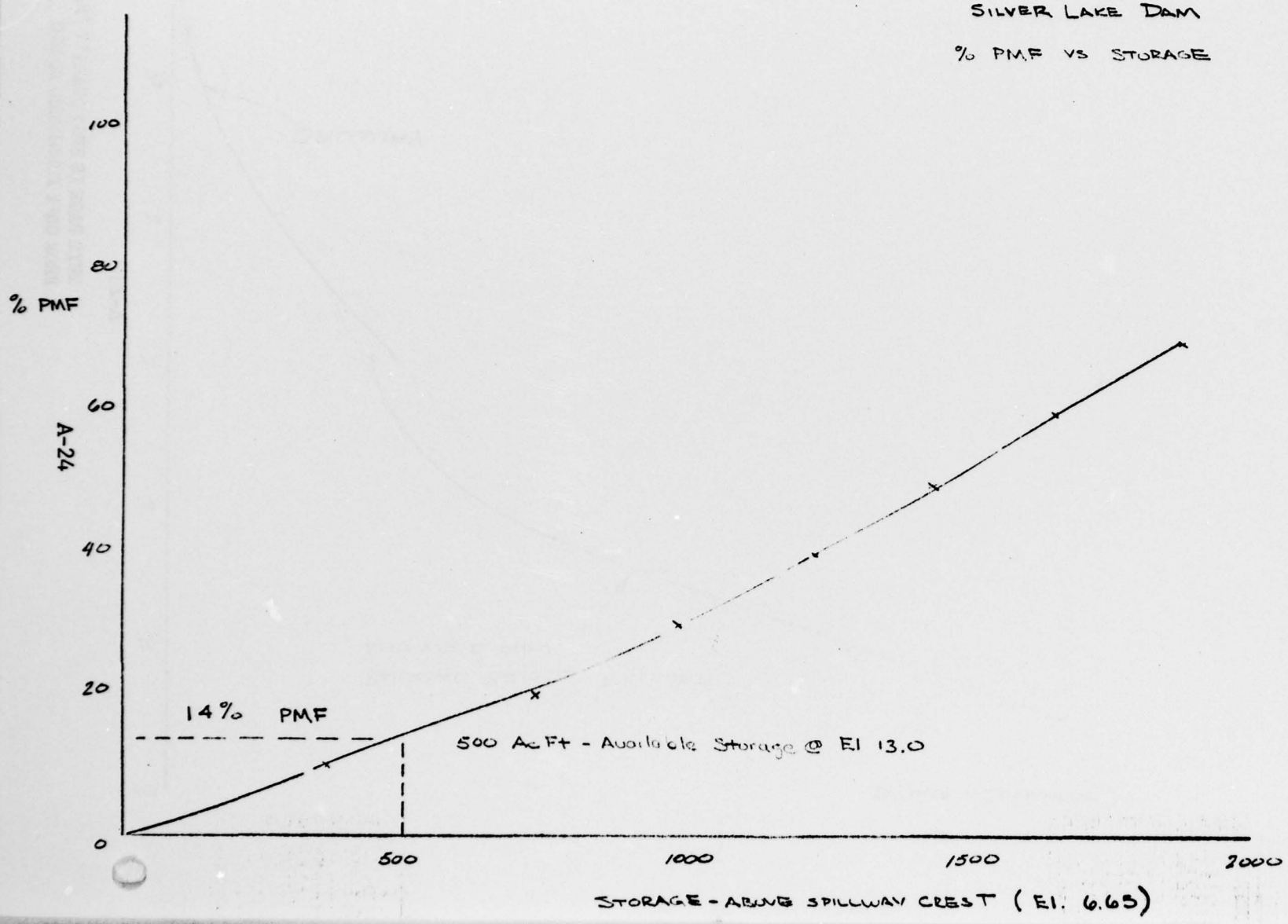
PROJECT Silver Lake Dam

CHECKED BY _____



SILVER LAKE DAM

% PMF VS STORAGE



SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	7	REH	6/7/78	1800 001 195

Checked DEC

RESERVOIR DRAWDOWN ANALYSIS

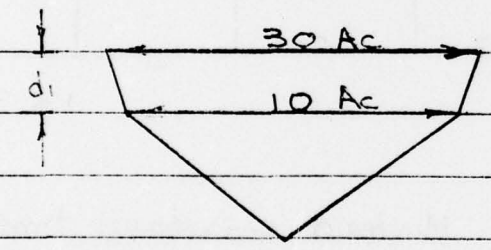
Storage @ spillway crest = 60 Ac Ft

Surface area @ Crest = 30 Ac

Depth of water @ spillway = 6.65 − 0.65 = 6'

Assume surface area @ el 0.65 = 0 Ac.

Section through lake (assume $d_1 = 2'$)



$$\text{Storage} = \frac{(30+X)(2)}{2} + \frac{X(4)}{2}$$

$$60 = 30 + X + 2X$$

$$30 = 3X$$

$$X = 10 \text{ Ac}$$

Elev	Area (Ac)
6.65	30
5.65	20
4.65	10
3.65	7.5
2.65	5.0
1.65	2.5
0.65	0

O'BRIEN & GERE ENGINEERS

SUBJECT	SHEET	BY	DATE	JOB NO
SILVER LAKE DAM	8	REH	6/7/78	1800 001

Checked DBC

Begin drawdown @ elevation 6.65

Assume no tailwater condition, no inflow

El	Area (Ac)	(cf x 10^6) INCREMENTAL Storage	(ft) HW	(cfs) * Q	(cfs) $\overline{Q}_{AVE}$	(hrs) Time
6.65	30		6	115		
		1.742			95	5.0
4.65	10		4	75		
		.653			50	3.6
2.65	5		2	25		
		.218			13	4.7
0.65	0		0	0		

13.3 hrs

Minimum drawdown time ≈ 13 hrs

* Discharges determined from culvert capacity charts published by the Bureau of Public Roads (1/63) and presented in "Handbook of Concrete Culvert Pipe Hydraulic Assume inlet control, headwall entrance.

****
HEC-1 VERSION DATED JAN 1973
UPDATED AUG 74
CHANGE NO. 01
****

PMF ROUTING
HAVEN LAKE DAM AND SILVER LAKE DAM
O'BRIEN + GERE - JUSTIN AND COURTNEY DIV

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
48	0	30	1	0	0	0	0	2	0

JOPER 5 NWT 0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 9 LRTIO= 1

RTIOS= .10 .20 .30 .40 .50 .60 .70 .80 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
1	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
0	1	30.00	0.00	0.00	0.00	0.000	0	1	0

PRECIP DATA

NP	STORM	DAJ	DAK
12	0.00	0.00	0.00

PRECIP PATTERN

0.00 0.00 .30 .50 .70 1.10 3.60 5.90 1.60 .90
.90 .90

LOSS DATA

STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

UNIT HYDROGRAPH DATA
TP= 2.70 CP= .48 NTA= 0

RECESSION DATA
STRTQ= 0.00 QRCSN= 0.00 RTIOR= 1.00
APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC= 5.84 AND R= 7.77 INTERVALS

UNIT HYDROGRAPH 45 END-OF-PERIOD ORDINATES, LAG= 2.70 HOURS, CP= .48 VOL= 1.00

234.	869.	1746.	2626.	3250.	3443.	3208.	2820.	2479.	2179.
1916.	1684.	1481.	1302.	1144.	1006.	884.	777.	683.	601.
528.	464.	408.	359.	315.	277.	244.	214.	188.	166.
146.	128.	112.	99.	87.	76.	67.	59.	52.	46.
40.	35.	31.	27.	24.					

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
0.30	0.00	0.00	0.

1	1	60	.50	.50	378.
1	2	30	.70	.70	1122.
1	2	60	1.10	1.10	2526.
1	3	30	3.60	3.60	5309.
1	3	60	5.90	5.90	10925.
1	4	30	1.60	1.60	19632.
1	4	60	.90	.90	29789.
1	5	30	.90	.90	39164.
1	5	60	.90	.90	45731.
1	6	30	0.00	0.00	48280.
1	6	60	0.00	0.00	47164.
1	7	30	0.00	0.00	44104.
1	7	60	0.00	0.00	40313.
1	8	30	0.00	0.00	36129.
1	8	60	0.00	0.00	31924.
1	9	30	0.00	0.00	28064.
1	9	60	0.00	0.00	24671.
1	10	30	0.00	0.00	21688.
1	10	60	0.00	0.00	19066.
1	11	30	0.00	0.00	16761.
1	11	60	0.00	0.00	14734.
1	12	30	0.00	0.00	12953.
1	12	60	0.00	0.00	11387.
1	13	30	0.00	0.00	10010.
1	13	60	0.00	0.00	8800.
1	14	30	0.00	0.00	7736.
1	14	60	0.00	0.00	6800.
1	15	30	0.00	0.00	5978.
1	15	60	0.00	0.00	5255.
1	16	30	0.00	0.00	4620.
1	16	60	0.00	0.00	4061.
1	17	30	0.00	0.00	3570.
1	17	60	0.00	0.00	3139.
1	18	30	0.00	0.00	2759.
1	18	60	0.00	0.00	2426.
1	19	30	0.00	0.00	2132.
1	19	60	0.00	0.00	1874.
1	20	30	0.00	0.00	1648.
1	20	60	0.00	0.00	1449.
1	21	30	0.00	0.00	1273.
1	21	60	0.00	0.00	1119.
1	22	30	0.00	0.00	984.
1	22	60	0.00	0.00	865.
1	23	30	0.00	0.00	761.
1	23	60	0.00	0.00	662.
		SUM	16.40	16.40	629809.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	48280.	36419.	13121.	13121.	629812.
INCHES		11.29	16.27	16.27	16.27
AC-FT		18068.	26039.	26039.	26039.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 1

0.	0.	7.	38.	112.	253.	531.	1093.	1963.	2979.
3916.	4573.	4828.	4716.	4411.	4031.	3613.	3192.	2806.	2467.
2169.	1907.	1676.	1473.	1295.	1139.	1001.	880.	774.	680.
598.	526.	462.	406.	357.	314.	276.	243.	213.	187.
165.	145.	127.	112.	98.	87.	76.	66.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	4828.	3642.	1312.	1312.	62981.
INCHES		1.13	1.63	1.63	1.63

0.	0.	14.	76.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7833.	9146.	9656.	9433.	8822.	8063.	7226.	6385.	5613.	4934.
4338.	3813.	3352.	2947.	2591.	2277.	2002.	1760.	1547.	1360.
1196.	1051.	924.	812.	714.	628.	552.	485.	426.	375.
330.	290.	255.	224.	197.	173.	152.	132.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	9656.	7284.	2624.	2624.	125962.
INCHES		2.26	3.25	3.25	3.25
AC-FT		3614.	5208.	5208.	5208.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 3

0.	0.	21.	113.	337.	758.	1593.	3278.	5890.	8937.
11749.	13719.	14484.	14149.	13232.	12094.	10839.	9577.	8419.	7401.
6506.	5720.	5028.	4420.	3886.	3416.	3003.	2640.	2321.	2040.
1793.	1577.	1386.	1218.	1071.	942.	828.	728.	640.	562.
494.	435.	382.	336.	295.	260.	228.	199.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	14484.	10926.	3936.	3936.	188944.
INCHES		3.39	4.88	4.88	4.88
AC-FT		5420.	7812.	7812.	7812.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 4

0.	0.	28.	151.	449.	1011.	2124.	4370.	7853.	11916.
15666.	18292.	19312.	18865.	17643.	16125.	14452.	12770.	11226.	9868.
8675.	7626.	6704.	5894.	5181.	4555.	4004.	3520.	3094.	2720.
2391.	2102.	1848.	1625.	1428.	1255.	1104.	970.	853.	750.
659.	579.	509.	448.	394.	346.	304.	265.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	19312.	14568.	5248.	5248.	251925.
INCHES		4.52	6.51	6.51	6.51
AC-FT		7227.	10415.	10415.	10415.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 5

0.	0.	35.	189.	561.	1263.	2654.	5463.	9816.	14895.
19582.	22865.	24140.	23582.	22054.	20156.	18065.	15962.	14032.	12336.
10844.	9533.	8380.	7367.	6476.	5693.	5005.	4400.	3868.	3400.
2989.	2628.	2310.	2031.	1785.	1569.	1380.	1213.	1066.	937.
824.	724.	637.	560.	492.	433.	380.	331.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	24140.	18209.	6561.	6561.	314906.
INCHES		5.65	8.14	8.14	8.14
AC-FT		9034.	13019.	13019.	13019.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 6

0.	0.	42.	227.	673.	1516.	3185.	6555.	11779.	17874.
23499.	27438.	28968.	28298.	26465.	24188.	21678.	19155.	16839.	14803.
13013.	11440.	10056.	8841.	7772.	6832.	6006.	5280.	4641.	4080.
3587.	3153.	2772.	2437.	2142.	1883.	1656.	1455.	1279.	1125.
989.	869.	764.	672.	590.	519.	456.	397.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	28968.	21851.	7873.	7873.	377887.
INCHES		6.78	9.76	9.76	9.76
AC-FT		10841.	15623.	15623.	15623.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 7

0.	0.	49.	264.	785.	1768.	3716.	7648.	13742.	20853.
27415.	32011.	33796.	33014.	30875.	28219.	25291.	22347.	19645.	17270.
15182.	13346.	11733.	10314.	9067.	7971.	7007.	6160.	5416.	4760.
4185.	3679.	3234.	2843.	2499.	2197.	1931.	1698.	1493.	1312.
				648	606.	532.	464.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	33796.	25493.	9185.	9185.	440869.
INCHES		7.90	11.39	11.39	11.39
AC-FT		12648.	18227.	18227.	18227.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 8

0.	0.	56.	302.	898.	2021.	4247.	8740.	15706.	23831.
31331.	36584.	38624.	37731.	35286.	32250.	28903.	25539.	22451.	19737.
17351.	15253.	13409.	11787.	10362.	9109.	8008.	7040.	6189.	5440.
4783.	4204.	3696.	3249.	2856.	2511.	2207.	1940.	1706.	1500.
1318.	1159.	1019.	896.	787.	692.	608.	530.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	38624.	29135.	10497.	10497.	503850.
INCHES		9.03	13.02	13.02	13.02
AC-FT		14455.	20831.	20831.	20831.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 9

0.	0.	70.	378.	1122.	2526.	5309.	10925.	19632.	29789.
39164.	45731.	48280.	47164.	44108.	40313.	36129.	31924.	28064.	24671.
21688.	19066.	16761.	14734.	12953.	11387.	10010.	8800.	7736.	6800.
5978.	5255.	4620.	4061.	3570.	3139.	2759.	2426.	2132.	1874.
1648.	1449.	1273.	1119.	984.	865.	761.	662.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	48280.	36419.	13121.	13121.	629812.
INCHES		11.29	16.27	16.27	16.27
AC-FT		18068.	26039.	26039.	26039.

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HYDROGRAPH ROUTING

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
2	1	0	0	0	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.000	0.00	1	1

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA
1	0	0	0.000	0.000	0.000	-1.

STORAGE=	0.	57.	143.	260.	406.	790.	1437.	2091.	2462.	0.
OUTFLOW=	0.	413.	1191.	1375.	2379.	6241.	25057.	42240.	51938.	0.

STATION 2, PLAN 1, RTIO 1

0.	0.	1.	7.	24.	66.	151.	324.	684.	1202.
1343.	1970.	2752.	3448.	3833.	3966.	3917.	3740.	3484.	3192.
2891.	2597.	2336.	2147.	1958.	1774.	1600.	1436.	1352.	1313.
1270.	1225.	1132.	914.	747.	618.	517.	436.	378.	331.
291.	255.	224.	197.	173.	152.	133.	117.		

STOR

0.	0.	0.	1.	3.	9.	21.	44.	87.	150.
240.	347.	443.	513.	551.	564.	559.	541.	516.	487.
457.	428.	400.	373.	345.	318.	293.	269.	245.	220.
193.	165.	137.	112.	94.	79.	68.	59.	52.	45.
40.	35.	31.	27.	24.	21.	18.	16.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	[illegible]	[illegible]	1305.	1305.	62619.

STATION 2, PLAN 1, RTIO 2

0.	0.	2.	13.	49.	132.	303.	695.	1240.	1763.
3291.	5083.	6960.	8899.	9070.	8599.	7883.	7075.	6268.	5910.
5471.	4990.	4505.	4038.	3600.	3198.	2833.	2505.	2259.	2059.
1865.	1681.	1509.	1369.	1331.	1289.	1245.	1199.	997.	811.
667.	555.	467.	398.	349.	306.	268.	235.		

STOR

0.	0.	0.	2.	7.	18.	41.	88.	174.	316.
497.	675.	814.	881.	887.	871.	846.	818.	791.	757.
713.	666.	617.	571.	528.	488.	452.	419.	389.	360.
331.	305.	279.	256.	232.	205.	177.	148.	122.	101.
85.	72.	63.	55.	48.	42.	37.	32.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	9070.	6726.	2609.	2609.	125234.
INCHES		2.09	3.24	3.24	3.24
AC-FT		3337.	5178.	5178.	5178.

STATION 2, PLAN 1, RTIO 3

0.	0.	3.	20.	73.	198.	462.	1080.	1433.	3125.
5613.	10216.	13131.	14020.	13773.	12940.	11835.	10615.	9402.	8283.
7286.	6406.	5961.	5535.	5058.	4573.	4103.	3661.	3254.	2884.
2551.	2288.	2088.	1893.	1708.	1534.	1374.	1337.	1296.	1252.
1206.	1033.	838.	688.	571.	479.	407.	356.		

STOR

0.	0.	0.	3.	10.	27.	62.	131.	268.	480.
727.	926.	1027.	1057.	1049.	1020.	982.	940.	898.	860.
826.	795.	762.	720.	672.	624.	578.	534.	493.	457.
423.	393.	364.	335.	308.	283.	259.	236.	209.	182.
153.	126.	104.	87.	74.	64.	56.	49.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	14020.	10322.	3913.	3913.	187842.
INCHES		3.20	4.85	4.85	4.85
AC-FT		5121.	7766.	7766.	7766.

STATION 2, PLAN 1, RTIO 4

0.	0.	4.	26.	98.	264.	643.	1245.	2070.	4643.
9626.	15141.	17887.	18789.	18388.	17260.	15781.	14153.	12536.	11044.
9715.	8542.	7509.	6601.	6040.	5636.	5168.	4684.	4209.	3760.
3345.	2967.	2625.	2335.	2135.	1938.	1750.	1573.	1409.	1345.
1305.	1262.	1216.	1086.	877.	719.	595.	498.		

STOR

0.	0.	1.	4.	13.	36.	82.	177.	361.	631.
906.	1096.	1191.	1222.	1208.	1169.	1118.	1062.	1006.	955.
909.	869.	833.	802.	770.	730.	683.	635.	588.	543.
502.	465.	431.	400.	371.	342.	315.	289.	265.	241.
215.	188.	159.	131.	108.	91.	77.	66.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	18789.	14072.	5218.	5218.	250443.
INCHES		4.36	6.47	6.47	6.47
AC-FT		6981.	10354.	10354.	10354.

STATION 2, PLAN 1, RTIO 5

0.	0.	5.	33.	122.	330.	823.	1321.	2867.	6137.
14342.	19504.	22503.	23522.	22994.	21577.	19727.	17692.	15670.	13805.
12143.	10677.	9387.	8252.	7254.	6377.	5949.	5519.	5042.	4557.
4087.	3646.	3241.	2872.	2539.	2281.	2091.	1886.	1701.	1528.

1089.	1248.	1349.	1389.	1388.	1318.	1294.	1209.	1114.	1010.
993.	942.	898.	859.	824.	794.	761.	718.	671.	622.
576.	532.	492.	455.	422.	392.	363.	334.	307.	282.
259.	235.	208.	181.	152.	125.	103.	87.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	23522.	17846.	6521.	6521.	312987.
INCHES		5.53	8.09	8.09	8.09
AC-FT		8854.	12940.	12940.	12940.

STATION 2, PLAN 1, RTIO 6

0.	0.	6.	39.	147.	395.	1004.	1463.	3761.	9144.
17802.	23552.	26920.	28126.	27602.	25999.	23760.	21252.	18810.	16568.
14573.	12813.	11264.	9902.	8705.	7653.	6727.	6091.	5701.	5239.
4755.	4277.	3824.	3404.	3020.	2673.	2366.	2165.	1967.	1778.
1599.	1433.	1351.	1311.	1268.	1223.	1119.	902.		

STOR

0.	0.	1.	5.	20.	54.	122.	273.	544.	898.
1188.	1386.	1508.	1554.	1534.	1473.	1393.	1306.	1222.	1145.
1076.	1016.	963.	916.	874.	838.	806.	775.	736.	690.
642.	595.	550.	508.	470.	436.	405.	375.	346.	319.
293.	268.	244.	219.	192.	163.	135.	111.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	28126.	21481.	7822.	7822.	375452.
INCHES		6.66	9.70	9.70	9.70
AC-FT		10657.	15523.	15523.	15523.

STATION 2, PLAN 1, RTIO 7

0.	0.	6.	46.	171.	471.	1182.	1761.	4599.	12193.
21150.	27419.	31282.	32777.	32191.	30329.	27812.	24996.	21996.	19342.
17004.	14949.	13141.	11553.	10156.	8928.	7848.	6900.	6160.	5790.
5336.	4852.	4371.	3912.	3484.	3093.	2738.	2420.	2204.	2005.
1814.	1633.	1464.	1358.	1319.	1276.	1232.	1164.		

STOR

0.	0.	1.	6.	23.	63.	142.	316.	627.	995.
1303.	1527.	1674.	1731.	1709.	1638.	1542.	1435.	1332.	1241.
1160.	1089.	1027.	972.	924.	882.	845.	812.	782.	745.
700.	652.	604.	559.	516.	477.	442.	410.	381.	352.
324.	297.	273.	249.	224.	197.	169.	140.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	32777.	25104.	9121.	9121.	437827.
INCHES		7.78	11.31	11.31	11.31
AC-FT		12455.	18101.	18101.	18101.

STATION 2, PLAN 1, RTIO 8

0.	0.	7.	52.	196.	549.	1225.	2091.	5471.	15291.
24510.	31197.	35710.	37448.	36786.	34661.	31785.	28571.	25349.	22176.
19452.	17089.	15020.	13203.	11607.	10203.	8970.	7885.	6932.	6173.
5807.	5354.	4870.	4389.	3928.	3499.	3106.	2750.	2431.	2211.
2012.	1820.	1639.	1470.	1360.	1320.	1278.	1233.		

STOR

0.	0.	1.	7.	27.	72.	165.	364.	713.	1101.
1419.	1671.	1842.	1908.	1883.	1802.	1693.	1571.	1448.	1338.
1244.	1163.	1092.	1029.	974.	926.	884.	846.	813.	783.
747.	702.	654.	606.	560.	518.	479.	441.	412.	382.
353.	325.	298.	274.	250.	225.	198.	170.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

STATION 2, PLAN 1, RTIO 9

0.	0.	9.	66.	245.	707.	1236.	2903.	8260.	20600.
30645.	38957.	44614.	46792.	45992.	43338.	39740.	35716.	31687.	27941.
24557.	21422.	18790.	16508.	14509.	12754.	11212.	9856.	8665.	7617.
6696.	6078.	5685.	5222.	4737.	4261.	3808.	3389.	3007.	2661.
2359.	2158.	1960.	1771.	1593.	1427.	1349.	1309.		

STOR

0.	0.	1.	9.	34.	89.	210.	458.	859.	1284.
1650.	1966.	2182.	2265.	2234.	2133.	1996.	1843.	1689.	1547.
1420.	1312.	1222.	1143.	1074.	1014.	961.	914.	873.	837.
805.	773.	734.	688.	640.	593.	548.	507.	469.	434.
403.	374.	345.	318.	292.	267.	244.	218.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	46792.	35949.	13018.	13018.	624858.
INCHES		11.15	16.15	16.15	16.15
AC-FT		17835.	25834.	25834.	25834.

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HYDROGRAPH ROUTING

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
3	1	0	0	0	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.000	0.00	1	1

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA
1	0	0	0.000	0.000	0.000	-1.

STORAGE=	0.	12.	114.	279.	507.	780.	1149.	1564.	2041.	2874.
OUTFLOW=	0.	65.	1135.	2858.	4392.	8902.	16008.	24872.	35109.	52707.

STATION 3, PLAN 1, RTIO 1

0.	0.	0.	1.	4.	12.	32.	82.	232.	484.
763.	1080.	1534.	2090.	2640.	3016.	3242.	3385.	3441.	3416.
3324.	3182.	3007.	2803.	2537.	2299.	2082.	1882.	1709.	1575.
1475.	1394.	1318.	1213.	1078.	938.	807.	690.	590.	506.
437.	379.	330.	287.	251.	219.	192.	168.		

STOR

0.	0.	0.	0.	1.	2.	6.	13.	28.	52.
79.	109.	153.	206.	258.	303.	336.	358.	366.	362.
349.	327.	302.	274.	249.	226.	205.	186.	169.	156.
147.	139.	132.	122.	109.	95.	83.	72.	62.	54.
47.	42.	37.	33.	29.	26.	24.	22.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3441.	3024.	1294.	1294.	62124.
INCHES		.94	1.61	1.61	1.61
AC-FT		1500.	2568.	2568.	2568.

STATION 3, PLAN 1, RTIO 2

0.	0.	0.	2.	8.	25.	65.	218.	484.	844.
1441.	2415.	3435.	4687.	6872.	7870.	8059.	7764.	7208.	6639.
6157.	5686.	5209.	4732.	4332.	4104.	3838.	3552.	3266.	2995.
2691.	2365.	2092.	1860.	1679.	1548.	1448.	1368.	1272.	1142.
999.	862.	737.	629.	539.	464.	401.	348.		

814.	369.	330.	320.	498.	4098.	4239.	3821.	3481.	3001.
263.	232.	206.	184.	166.	154.	144.	137.	127.	115.
101.	88.	76.	66.	57.	50.	44.	39.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	8059.	6268.	2591.	2591.	124351.
INCHES		1.94	3.21	3.21	3.21
AC-FT		3110.	5141.	5141.	5141.

STATION 3, PLAN 1, RTIO 3

0.	0.	0.	3.	12.	37.	121.	351.	672.	1241.
2351.	3869.	7273.	10666.	12505.	12990.	12647.	11837.	10796.	9684.
8635.	7725.	6941.	6334.	5807.	5303.	4812.	4367.	4144.	3881.
3597.	3309.	3035.	2744.	2409.	2130.	1890.	1700.	1564.	1461.
1379.	1287.	1162.	1021.	882.	756.	645.	552.		

STOR

0.	0.	0.	0.	2.	7.	17.	39.	70.	125.
231.	429.	682.	872.	967.	992.	975.	933.	879.	821.
764.	709.	661.	625.	593.	562.	532.	503.	470.	431.
389.	346.	306.	268.	236.	210.	187.	168.	155.	146.
138.	129.	117.	103.	90.	78.	67.	58.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	12990.	9836.	3886.	3886.	186529.
INCHES		3.05	4.82	4.82	4.82
AC-FT		4880.	7712.	7712.	7712.

STATION 3, PLAN 1, RTIO 4

0.	0.	0.	3.	16.	50.	182.	452.	879.	1758.
3414.	6920.	12145.	15670.	17432.	17672.	16967.	15760.	14385.	12904.
11469.	10136.	8935.	7976.	7134.	6475.	5929.	5419.	4924.	4447.
4200.	3944.	3663.	3374.	3096.	2827.	2478.	2189.	1941.	1741.
1594.	1484.	1397.	1310.	1193.	1053.	913.	783.		

STOR

0.	0.	0.	1.	3.	9.	23.	49.	90.	174.
362.	660.	949.	1132.	1216.	1227.	1194.	1136.	1065.	988.
913.	844.	782.	724.	673.	633.	600.	569.	539.	510.
478.	441.	399.	356.	315.	276.	243.	215.	192.	172.
158.	148.	139.	131.	120.	106.	93.	81.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	17672.	13455.	5180.	5180.	248637.
INCHES		4.17	6.42	6.42	6.42
AC-FT		6675.	10280.	10280.	10280.

STATION 3, PLAN 1, RTIO 5

0.	0.	0.	4.	19.	62.	243.	536.	1088.	2299.
4439.	11013.	16753.	20588.	22224.	22262.	21275.	19703.	17852.	15948.
14255.	12636.	11153.	9825.	8673.	7728.	6932.	6323.	5793.	5288.
4797.	4359.	4135.	3871.	3586.	3299.	3025.	2731.	2399.	2120.
1883.	1695.	1560.	1458.	1376.	1283.	1157.	1015.		

STOR

0.	0.	0.	1.	3.	11.	29.	57.	110.	226.
510.	890.	1184.	1363.	1440.	1442.	1396.	1322.	1235.	1146.
1058.	974.	897.	828.	766.	709.	661.	624.	592.	561.
531.	502.	469.	430.	387.	345.	304.	267.	235.	209.
186.	168.	155.	145.	137.	129.	116.	103.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME

0.	0.	1.	5.	23.	82.	301.	631.	1333.	3059.
6916.	14512.	20968.	24985.	26754.	26782.	25614.	23708.	21455.	19148.
16956.	15031.	13327.	11765.	10364.	9120.	8115.	7248.	6560.	6006.
5493.	4996.	4515.	4231.	3982.	3704.	3414.	3133.	2872.	2524.
2228.	1975.	1768.	1613.	1498.	1409.	1324.	1213.		

STOR

0.	0.	0.	1.	4.	13.	34.	66.	133.	309.
660.	1072.	1381.	1569.	1652.	1653.	1598.	1509.	1404.	1296.
1194.	1098.	1010.	929.	856.	792.	733.	680.	638.	605.
574.	544.	514.	483.	446.	405.	362.	320.	282.	247.
219.	195.	175.	160.	149.	141.	132.	122.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	26782.	20770.	7764.	7764.	372661.
INCHES		6.44	9.63	9.63	9.63
AC-FT		10304.	15407.	15407.	15407.

STATION 3, PLAN 1, RTIO 7

0.	0.	1.	6.	27.	105.	360.	754.	1614.	3659.
9555.	18087.	24988.	29314.	31261.	31261.	29915.	27758.	25140.	22400.
19810.	17461.	15414.	13668.	12066.	10629.	9353.	8299.	7399.	6675.
6110.	5593.	5094.	4610.	4274.	4033.	3759.	3471.	3187.	2923.
2592.	2284.	2023.	1806.	1640.	1519.	1425.	1344.		

STOR

0.	0.	0.	1.	5.	15.	40.	78.	160.	398.
814.	1246.	1569.	1771.	1862.	1862.	1799.	1698.	1576.	1448.
1327.	1217.	1118.	1028.	945.	870.	804.	744.	689.	645.
611.	580.	549.	520.	489.	454.	413.	370.	328.	289.
254.	224.	199.	179.	163.	151.	142.	134.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	31261.	24401.	9056.	9056.	434666.
INCHES		7.57	11.23	11.23	11.23
AC-FT		12106.	17971.	17971.	17971.

STATION 3, PLAN 1, RTIO 8

0.	0.	1.	7.	31.	128.	397.	844.	1885.	4265.
12459.	21620.	28881.	33610.	35757.	35737.	34199.	31729.	28799.	25705.
22706.	19988.	17578.	15494.	13735.	12124.	10680.	9398.	8333.	7428.
6697.	6129.	5612.	5112.	4627.	4282.	4042.	3770.	3481.	3198.
2932.	2605.	2295.	2032.	1813.	1645.	1522.	1428.		

STOR

0.	0.	0.	1.	6.	18.	43.	86.	186.	484.
965.	1412.	1751.	1971.	2072.	2071.	1999.	1883.	1747.	1603.
1463.	1335.	1223.	1122.	1031.	948.	873.	806.	746.	691.
647.	612.	581.	551.	521.	491.	455.	415.	372.	330.
290.	255.	225.	200.	179.	163.	151.	142.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	35757.	28026.	10349.	10349.	496740.
INCHES		8.69	12.84	12.84	12.84
AC-FT		13904.	20537.	20537.	20537.

STATION 3, PLAN 1, RTIO 9

0.	0.	1.	9.	39.	175.	468.	1046.	2655.	6899.
17418.	28077.	36483.	42086.	44700.	44676.	42770.	39706.	36057.	32232.
28557.	25137.	22054.	19355.	16998.	15012.	13288.	11720.	10320.	9080.
8083.	7220.	6540.	5987.	5475.	4978.	4498.	4223.	3972.	3694.
3404.	3124.	2864.	2512.	2218.	1967.	1761.	1608.		

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1736.	1576.	1432.	1306.	1196.	1097.	1008.	927.	854.	789.
731.	678.	637.	604.	573.	542.	513.	482.	445.	403.
360.	319.	280.	246.	218.	194.	174.	160.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	44700.	35211.	12941.	12941.	621144.
INCHES		10.92	16.05	16.05	16.05
AC-FT		17469.	25680.	25680.	25680.

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PEAK FLOW SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS

OPERATION	STATION	PLAN	RATIOS APPLIED TO FLOWS .10	.20	.30	.40	.50	.60	.70	.80	1.00
HYDROGRAPH AT	1	1	4828.	9656.	14484.	19312.	24140.	28968.	33796.	38624.	48280.
		2	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROUTED TO	2	1	3966.	9070.	14020.	18789.	23522.	28126.	32777.	37448.	46792.
		2	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROUTED TO	3	1	3441.	8059.	12990.	17672.	22262.	26782.	31261.	35757.	44700.
		2	0.	0.	0.	0.	0.	0.	0.	0.	0.